SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

Sessions 38-40: Nobs, Slobs, Sustainability & Social Collapse Week

Exploring & Replicating Motesharrei, Rivas, & Kalnay (2014)

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Methodological and Ideological Options

Human and nature dynamics (HANDY): Modeling inequality and use of resources in the collapse or sustainability of societies

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ABSTRACT

There are widespread concerns that current trends in resource-use are unsustainable, but possibilities of overshoot/collapse remain controversial. Collapses have occurred frequently in history, often followed by centuries of economic, intellectual, and population decline. Many different natural and social phenomena have been invoked to explain specific collapses, but a general explanation remains elusive.

In this paper, we build a human population dynamics model by adding accumulated wealth and economic inequality to a predator–prey model of humans and nature. The model structure, and simulated scenarios that offer significant implications, are explained. Four equations describe the evolution of Elites, Commoners, Nature, and Wealth. The model shows Economic Stratification or Ecological Strain can independently lead to collapse, in agreement with the historical record.

The measure "Carrying Capacity" is developed and its estimation is shown to be a practical means for early detection of a collapse. Mechanisms leading to two types of collapses are discussed. The new dynamics of this model can also reproduce the irreversible collapses found in history. Collapse can be avoided, and population can reach a steady state at maximum carrying capacity if the rate of depletion of nature is reduced to a sustainable level and if resources are distributed equitably.

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Weak States, Cocky States

- ”Nal Kormerex Khesterex”
  - [What doesn’t grow must decay]
  - Klingon Proverb
- “Overshoot your headlights and you’ll be six feet under the ground…”
  - Mr Small, Driver’s Ed Class, 1982
- “Everybody needs a Thneed™!”
  - The Once-ler

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Sustainability & Weak States

- Many human cultures have been more on a knife-edge than they thought.
- Crack a History Book
  - Akkadians
  - Romans
  - Polynesians
- Crack Jane's Intel Review
  - Syria
  - Zimbabwe

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”Give it a little Push!”

- We’ve done a number things so far that will make some elements of this exercise seem rather… familiar
  - Predator – Prey
  - Logisical Growth
  - Carying Capacity

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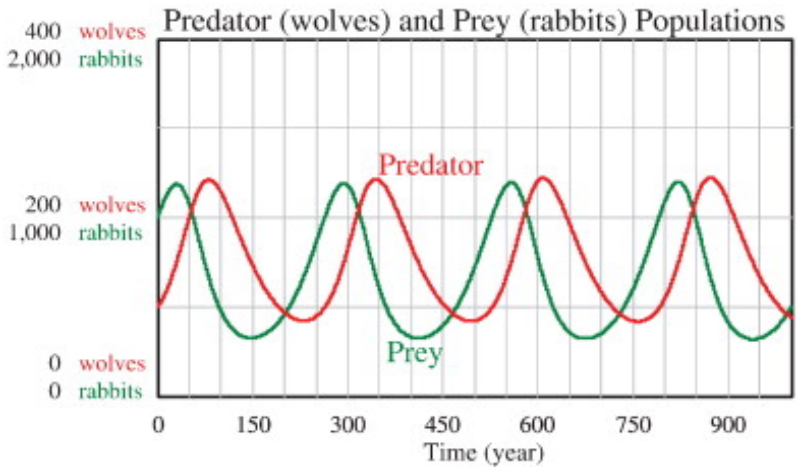
Predator Prey…

$$\frac{dx}{dt} = (ay)x - bx$$

$$\frac{dy}{dt} = cy - (dx)y$$



- Doesn't work on people… or "fableulous" grasshoppers

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Human vs Animals

- Humans don't immediately consume raw resources.
  - Foxes Eat Rabbits
  - Humans Eat High Fructose Corn Syrup.
- Human Plan Ahead
  - We store surplus resources
  - When production of immediate resources stops, we go to the reserves.
- Human Surplus Allocation is not Even
  - Most to "nobs" less to "slobs"
- Both change the dynamics of the lagged oscillations of LV or derivable Carrying Capacity of Logistical Growth.

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Nobs vs Slobs?

- HANDY (Human and Nature Dynamics) model was designed to emulate both wealth accrual and unequal distribution.
  - Xe : Elites
  - Xc : Commoners
  - Y : Natural Resources
  - W : “Wealth”

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HANDY Equations

$$\frac{dx_c}{dt} = \beta_c x_c - \alpha_c x_c$$

$$\frac{dx_e}{dt} = \beta_e x_e - \alpha_e x_e$$

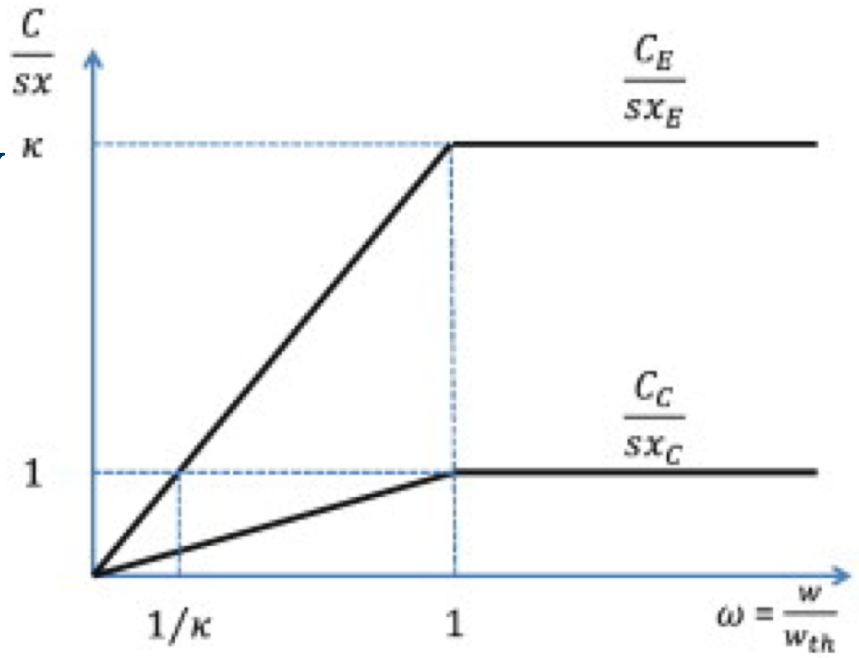
$$\frac{dy}{dt} = \gamma y(\lambda - y) - \delta x_c y$$

$$\frac{dw}{dt} = \delta x_c y - C_c - C_e$$

- β = const. birth rates
- α = death rates, $f(w)$
- γ = unrestricted natural growth
- λ = carrying capacity
- δ = depletion rate
- C = consumption, $f(w)$

Consumption Rates

- Consumption is based on availability of resources and class



a) Consumption rates in HANDY

- $$C_e = \min\left(1, \frac{w}{w_{th}}\right)\kappa s x_e$$

$$C_c = \min\left(1, \frac{w}{w_{th}}\right) s x_c$$

  - s="subsistence salary"
  - κ="wage" gap between fabs and proles
  - w_{th}=subsistence level

$$w_{th} = \rho(x_c + \kappa x_e)$$

$$\rho = 5 \times 10^{-3}€$$

$$s = 5 \times 10^{-4}€$$

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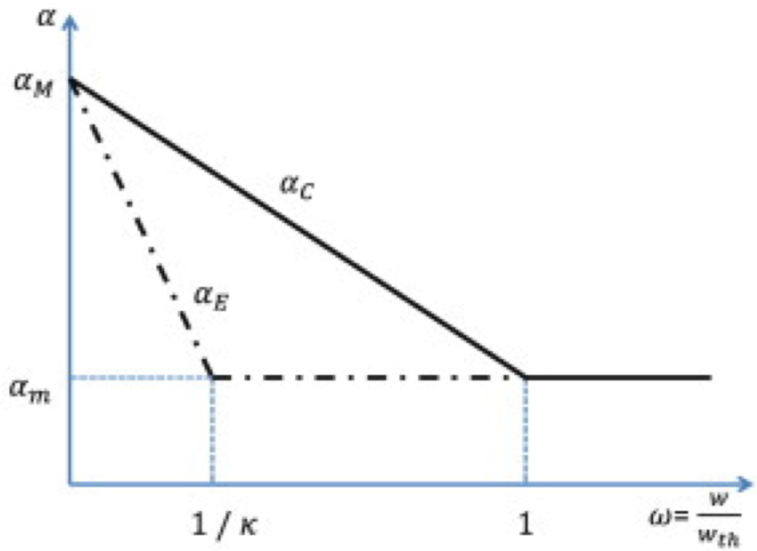
Death Rates

- "Eat to ~~live~~ not die"

$$\alpha = \alpha_{min} + \max\left(0, 1 - \frac{C}{sx}\right)\left(\alpha_{max} - \alpha_{min}\right)$$



b) Death rates in HANDY

- Posh folk have a latent response to resource drops

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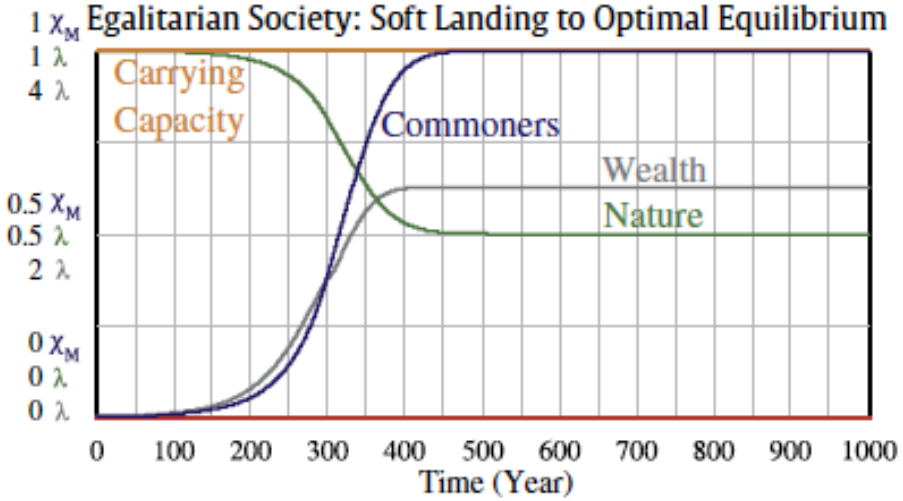
So let's do this!

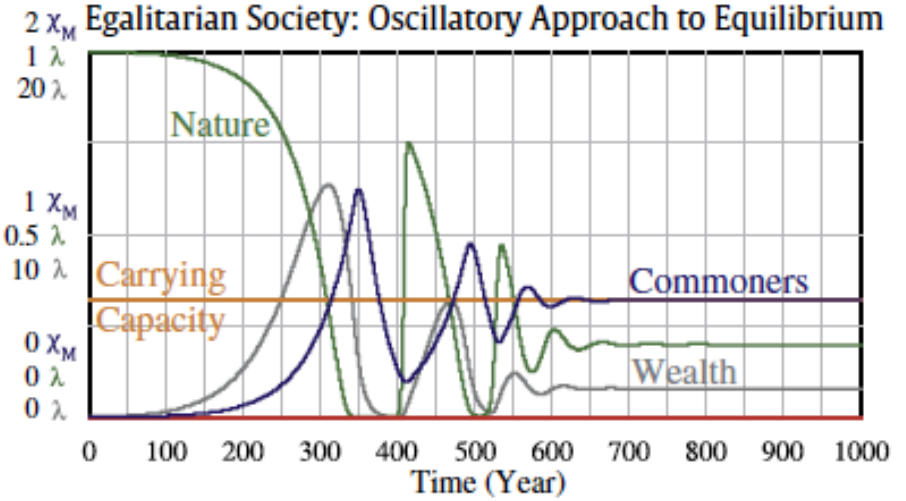
Parameter symbol	Parameter name	Typical value(s)
α_m	Normal (minimum) death rate	1.0×10^{-2} (US ~ 0.82×10^{-2})
α_M	Famine (maximum) death rate	7.0×10^{-2}
β_C	Commoner birth rate	3.0×10^{-2}
β_E	Elite birth rate	3.0×10^{-2} (US ~ 1.2×10^{-2})
s	Subsistence salary per capita	5.0×10^{-4}
ρ	Threshold wealth per capita	5.0×10^{-3}
γ	Regeneration rate of nature	1.0×10^{-2}
λ	Nature carrying capacity	$1.0 \times 10^{+2}$
κ	Inequality factor	1, 10, 100
δ	Depletion (production) factor	None ~$10^{-6 \text{ to } -5}$

Variable symbol	Variable name	Typical initial value(s)
x_C	Commoner population	$1.0 \times 10^{+2}$
x_E	Elite population	0, 1, 25
y	Nature	λ
w	Accumulated wealth	0

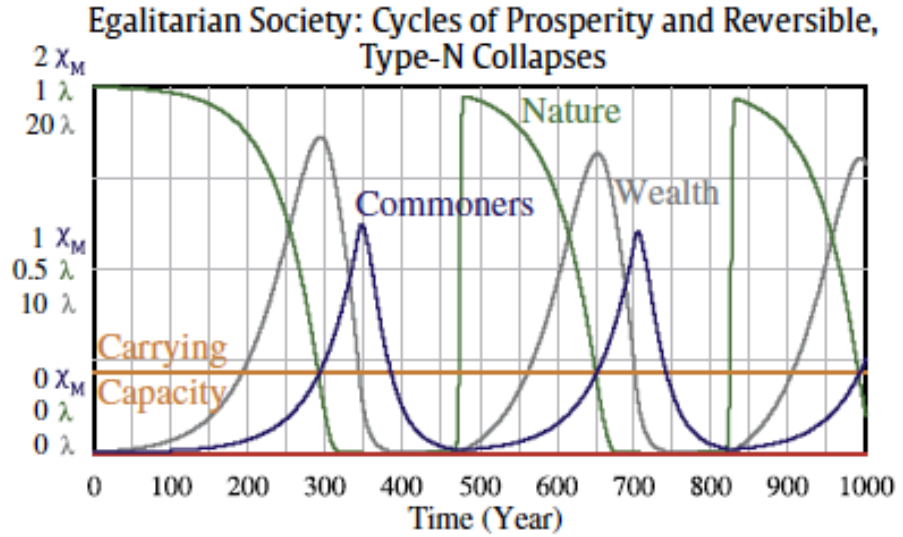
(a). List of parameters in HANDY. κ and δ take different values for different scenarios.
(b). List of state variables in HANDY. $x_E(0)$ takes different values for different scenarios.



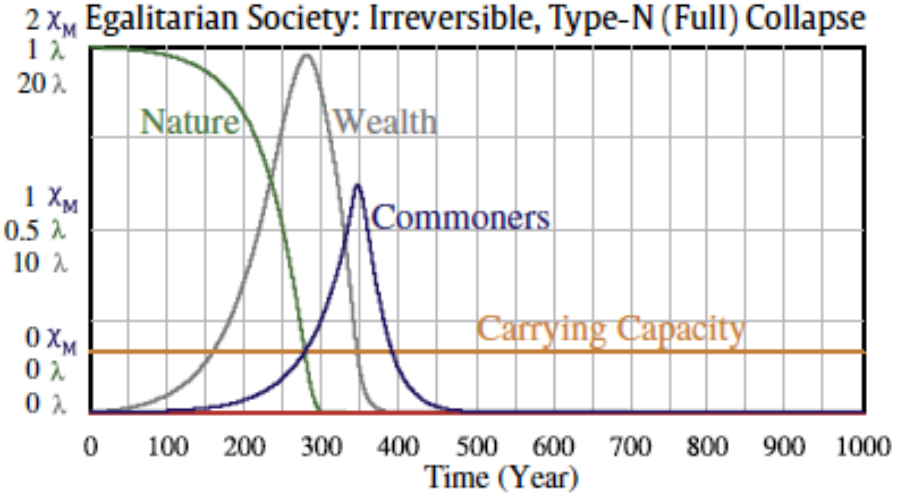
a) Soft landing to the optimal equilibrium when Elite population (marked in red) equals zero. Final population reaches the carrying capacity, which is at its maximum value, χ_M, in this scenario.



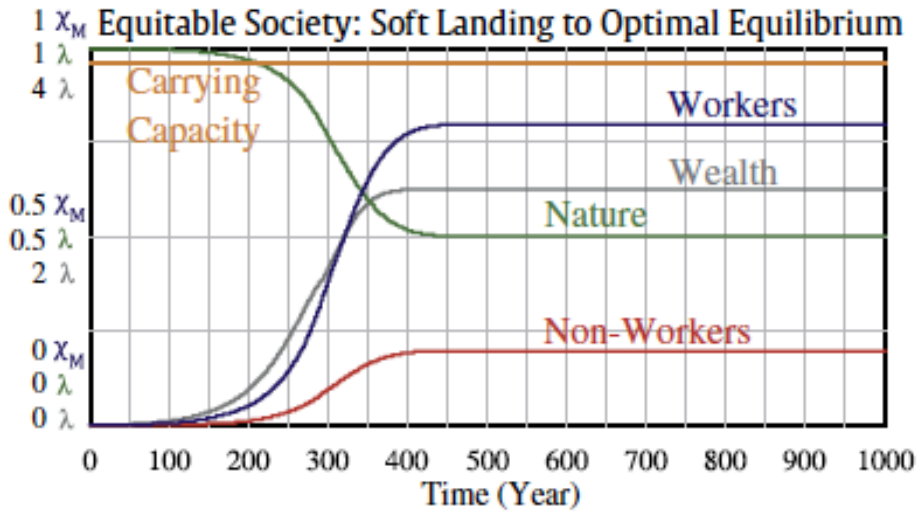
b) Oscillatory approach to equilibrium when Elite population (marked in red) equals zero. Final population converges to the carrying capacity, which is lower than its maximum value, χ_M, in this scenario.



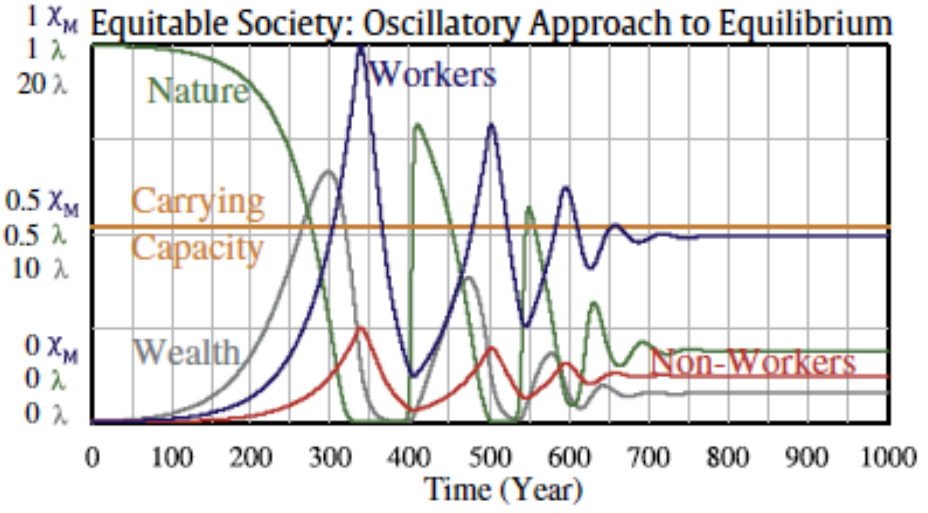
c) Cycles of prosperity, overshoot, (reversible Type-N) collapse, and revival when Elite population (marked in red) equals zero.



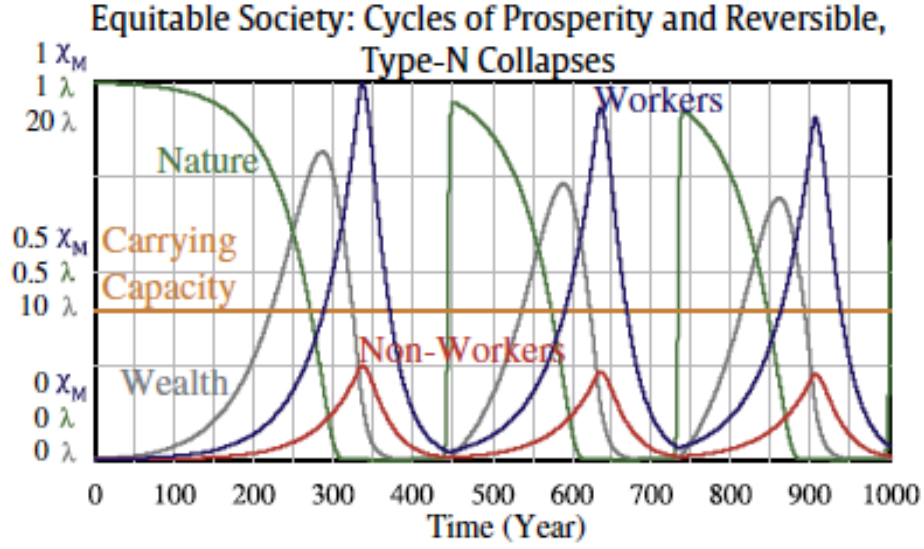
d) Irreversible Type-N collapse (full collapse) when Elite population (marked in red) equals zero. All the state variables collapse to *zero* in this scenario due to over-depletion.



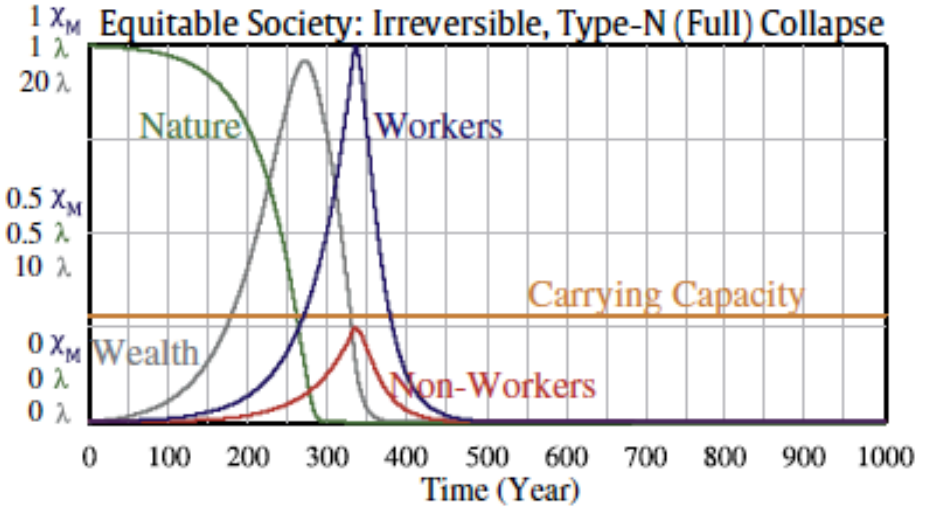
a) Equilibrium in the presence of both Workers and Non-Workers can be attained with slow growth and equitable salaries.



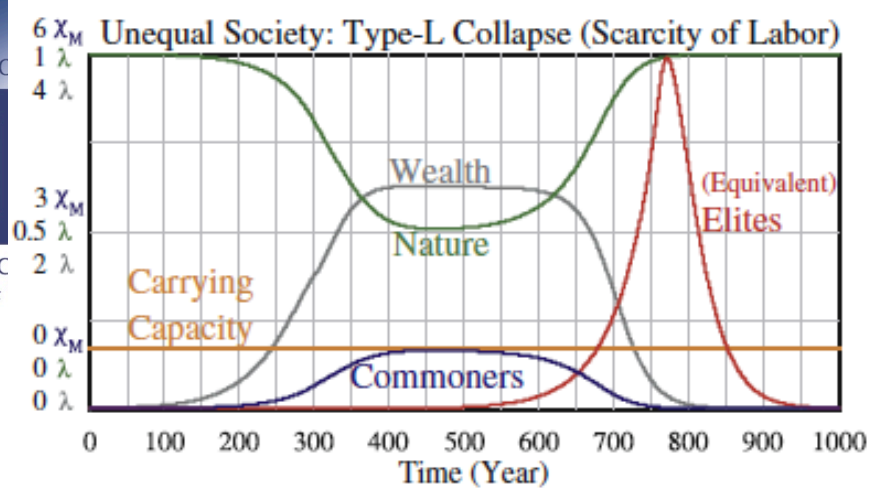
b) Oscillatory approach to equilibrium in the presence of both Workers and Non-Workers is possible when the overshoot is not too large.



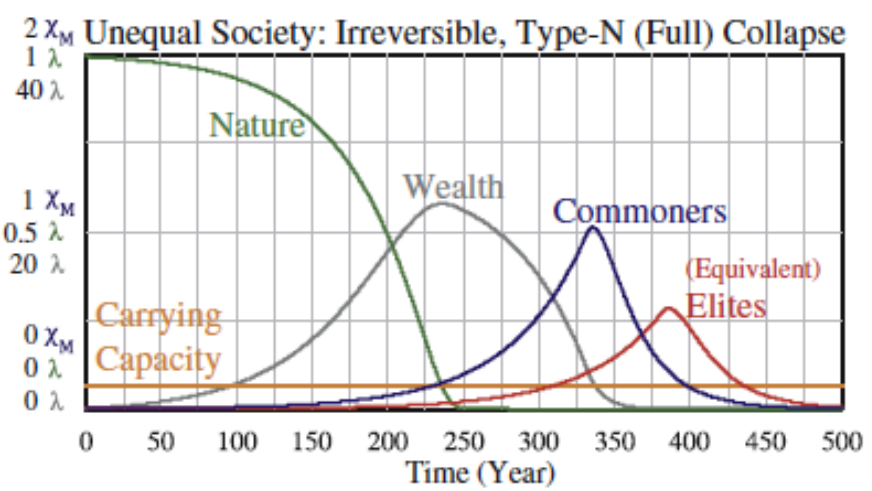
c) Cycles of prosperity, overshoot, (reversible Type-N) collapse, and revival in the presence of Workers and Non-Workers.



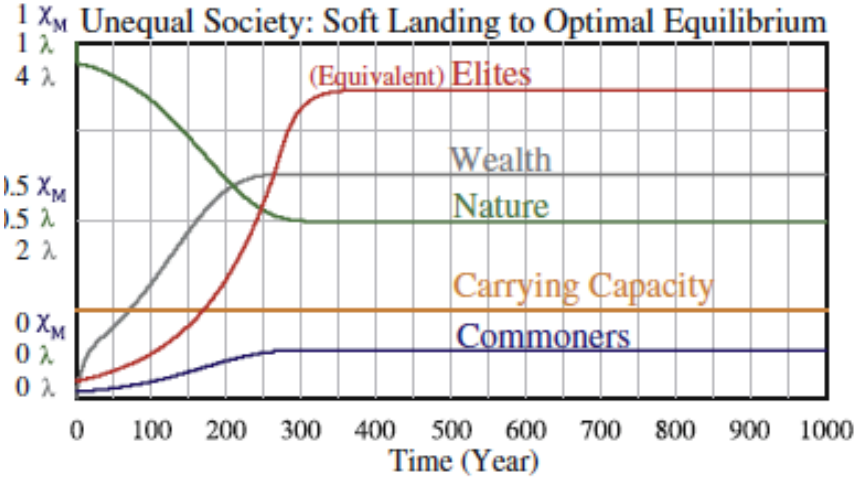
d) Irreversible Type-N collapse (full collapse) happens after a period of very fast growth.



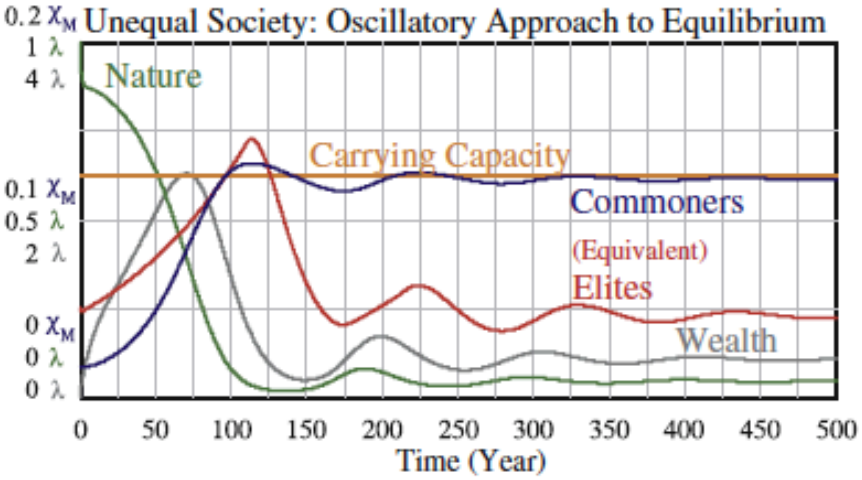
a) Population collapse following an apparent equilibrium due to a small initial Elite population when $\kappa = 100$. This scenario also shows a different route to a collapse, in which, although Nature eventually recovers, population does not.



b) A fast full collapse due to both over-depletion and inequality ($\kappa = 100$).



c) With moderate in equality ($\kappa = 10$), it is possible to attain an optimal equilibrium by controlling the birth rates.



d) With $\delta \gtrsim \delta_{***}$, it is still possible to oscillate and converge to an equilibrium ($\kappa = 10$).

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Ponderables…

- How would we construct HANDY 2.0?
- More Class Divisions?
- Different types of Resources?
- Exogenous Natural Shocks or Endogenous Natural Cycles?
- …